AN ASSESSMENT OF THE POTENTIAL FOR COAL/RESIDUAL OIL COPROCESSING

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Abstract

Among the promising new techniques to produce liquid hydrocarbon fuels from coal is coal/petroleum coprocessing based upon the use of heavy oil, tar sand bitumen and petroleum residua as "solvents" for the conversion of coal. Coprocessing is the simultaneous hydrogenation of coal and heavy oil fractions in specially designed reactors with coal contents by weight ranging from as low as 1% to potentially as high as 50-60% depending upon the technology employed. The results of a study on the potential for coal/residual oil coprocessing in the United States are addressed in this paper.

Introduction

Economics, the desire for less dependence upon the importation of foreign oil, and the depletion of lighter crudes in the United States has led the refining industry to process heavier crudes and bitumens. Upgrading and converting these heavy oils to distillate liquids using conventional petroleum thermal cracking, catalytic cracking and/or hydrocracking technologies has required the installation of costly equipment to handle the heavier oils. There exists in the literature sufficient evidence to suggest that heavy oil converts more readily in the presence of coal and that significant demetallization, desulfurization, denitrification and conversion of asphaltenes to oils also occurs. Thus the simultaneous conversion of coal and petroleum heavy oil fractions to produce distillate liquid products while upgrading the remaining heavy oil merits further investigation. This type of process, termed, coal/oil coprocessing has the potential for being an effective method for converting coal to liquids and for introducing coal liquids into the market place in a cost effective evolutionary manner while greatly reducing the capital investment associated with the historical approach for establishing a liquefaction industry. Among the additional potential benefits for the implementation and utilization of the coprocessing concept are:

a) Provision of a link or bridge between present day refining technology and a total coal based synfuels industry.

b) Improved economics compared to direct coal liquefaction due to smaller plant sizes, due to lower hydrogen requirements and the elimination of the use of process derived solvent recycle.

c) Residuum demetallization, improved product yields and mix.

d) Minimization of the production of gases and undesirable by-products; such as high sulfur coke.

e) Continued use of the U.S. hydrocarbon fuel infrastructure.

f) A means of extending petroleum reserves by reducing crude utilization requirements.

Coprocessing Schemes

The coprocessing schemes under consideration are generally an extension of two-stage coal liquefaction and application of residuum hydrocracking technology. It has been recognized that a possible synergism exists between coal derived liquids and petroleum derived residua. Coprocessing improves the quality of synthetic liquid fuel products from coal by diluting them directly with petroleum-derived liquids. Coal liquids contain a much higher proportion of aromatics compared to conventional petroleum-derived liquids, and the non-aromatic portion tends to be naphthenic rather than paraffinic. Coal liquids contain significant amounts of highly-polar compounds, and asphaltenes, but a relatively low amount of sulfur containing compounds.

Further, petroleum-derived naphtha, is low in nitrogen and oxygen. Coal-derived naphtha, on the other hand, has higher nitrogen and oxygen contents, is easier to reform, and has a higher octane number. Thus, combining coal-derived liquids with petroleum-derived liquid can provide some positive impacts on the overall product quality.

Broadly speaking, the coprocessing processes can be divided into four categories:

- Hydro-catalytic processes
- Extractive processes
- Thermal processes (non-catalytic)
- Hydro-thermal processes

The first category includes HRI, Lummus, CANMET, UOP, Chevron and Kerr-McKee processes. The second category includes processing variations incorporated for solids removal and deasphalting by Kerr-McGee, UOP and Lummus. The Cherry-P-process falls into the thermal process category. The process conditions are somewhat between those visbreaking and delayed coking. The Pyrosol process falls into the last category above and utilizes a mild hydrogenation of coal and heavy oil in the first stage. The second stage processes residuum under hydrogen pressure to produce more oil.

Refinery Integration Considerations

Since the late 1970's intensive capital investments in residuum upgrading and hydrotreating capacity have been made by the refinery industry for the conversion of heavier crude oil fractions to gasoline and distillate fuels. At the same time, the number of operating refineries in the United States has decreased from 319 to 191. As shown in Figure 1, this decrease has been accomplished primarily by the deactivation of a number of low capacity refineries operating in the hydroskimming or topping mode. The major driving force for this realignment in refining capacity has been largely due to a growing imbalance between the residuum content of available crude oil and a decrease in demand for residual fuel oil. Residual fuels such as No. 6 Fuel Oil, Bunker C, etc., are by-products of refining. As such, their production and availability are based on the demand for transportation and distillate fuels. Based upon data in the Oil and Gas Journal, residuum processing (thermal and hydrocracking) capacity as a percent of overall refining capacity has essentially increased 20% since 1980 to provide supply elasticity for the changing residual fuel demand, representing about 19% of the today's U.S. crude processing capacity. The future outlook is for this trend to continue as fuel oil is replaced by other energy forms such as coal, nuclear and natural gas. It is important to note that this processing of the heavy ends to yield prime products represents a reduction in the amount of crude oil required to meet gasoline and distillate fuel demand. Table 1 presents a profile of the Refining Industry in the U.S.
While coal liquefaction research and development has demonstrated significant progress in recent years, it has not addressed the fundamental causes for the high

cost of coal liquefaction, the high recycle oil requirements. In all direct liquefaction processes coal is slurried with a process derived recycle oil at a ypical ratio of 2:1 recycle oil to coal feed. Coprocessing of residuum and coal reduces the high cost associated with recycle oil by eliminating or reducing the requirements for recycle oil.

Coprocessing hydrocracking technology was originally developed for processing heavy crude with coal additives as a means of inhibiting the formation of coke. The CANMET hydrocracking process is based upon this comcept. This emerging technology shows promise of high demetallization, residuum hydrocracking, and high conversion of the pitch ($975^{o}F^{+}$) fraction. Coal additives include 1.0 - 2.0 wt.% of fine coal and ferrous sulfate.

Integration of the CANMET type process initially to an existing refinery and/or idle units is a first step toward utilization of coal and heavy oils (pitch and asphaltenes). A once through process arrangement without the use of a recycle stream may also be possible at lower coal concentrations.

Coprocessing technologies to be included in a staged approach are HRI, Lummus, and the Cherry-P processes which can process up to 50 wt.% of coal in heavy oil fraction.

Implementation of coprocessing will likely require additional refinery hydrogen generation. This will probably be based upon steam reforming of hydrocarbon gases and light naphtha. Steam reforming is a well established and adopted method of generating hydrogen. The expansion of reforming units can be accomplished more easily than integrating gasification units into refineries.

Hydrostabilization of product distillates are incorporated into a refinery to provide hydrotreatment and product stabilization prior to distribution outside the refinery complex. Further pretreatments for heteroatom removal may be required in a refinery utilizing coprocessing derived liquids.

The introduction of coal/residuum coprocessing will tend to reduce crude requirements. The extent of reduction will be dictated by market demands as well as product yields and qualities of the coprocessing distillate liquids. Other positive factors are 1) the use of existing refinery and infrastructure, 2) better economics than direct liquefaction, 3) compatability with the use of heavier crudes, and 4) the capability of installing a coprocessing unit independently from existing refinery operations.

Potential Coal Requirements

An estimate of the potential coal requirements for coal/oil coprocessing for the general refinery types in the United States is presented in Table 2. These capacities represent an upper limit for the application of coal/residua coprocessing as fuel oil production was assumed to be zero. It was also assumed that coprocessing is more economic than vacuum distillation (both cases are highly unlikely). Based upon a 1985 production capacity of 890 million tons of coal in the U.S.; coal producing capacity would have to increase by one-third if the upper limits of coal/residua coprocessing were achieved.

The most likely near term application for coal/oil coprocessing appears to be for residuum conversion capacity additions to low conversion refineries to improve profitability and to high conversion refineries to provide the capability for handling future feedstocks with increasingly higher residuum content. This premise is based on the assumption that present trends toward a heavier crude feedstocks and lighter reduced fuel oil requirements will continue. In terms of refinery capacity, average size Hydroskimming or Topping and High Conversion Refineries processing 25,000 and 150,000 bbl/day of heavy crude (25^{o} API), respectively, will require approximately 850 and 4,000 tons/day of coal, respectively, when coprocessing at slurry concentrations of 50%. These coal capacities are well within existing transportation and handling experience for coal fired industrial/utility boiler applications.

Process Economics

While the detailed engineering required to develop definitive coprocessing economics was beyond the scope of the effort, this paper would not be complete without presenting some guidelines. For this purpose, the installation of a coprocessing plant with a residuum throughput of 10,000 bbl/day (600-700 tons/day of coal) to a refinery (Figure 2) is estimated to cost of the order of $170MM. This cost includes coal handling and preparation, coal/residuum conversion and allowances for hydrocarbon steam reforming for hydrogen generation (~ 40% of the cost). Land and owner costs are not included in the estimate. In addition, it must be stressed that actual costs are refinery specific and will vary greatly, depending upon the adequacy and availability of refinery utility systems and the degree of integration capability.

Development Program Requirements

A potentially broad variety of coals and petroleum residua are candidates for coprocessing. The properties of these feedstocks will have to be investigated in bench scale experiments to define product quality. In addition, better characterization of hydrogen requirements are required to improve economies. These data are required to facilitate the design and integration of coprocessing units into existing refineries.

Conclusions

Although continued Research and Development are required to define product quality and yields, coprocessing of coal and residual oil shows promise. It is anticipated that initial application of coprocessing will involve the utilization of small amounts of coal (1-2 wt.%) in existing refineries. This will be followed by demonstration units (10,000-15,000 bbl/day) utilizing a staged approach, processing 30-40 wt.% coal. Commercial units should be able to process up to 50-60 wt.% coal and will be integrated into high and low conversion refineries using vacuum residua as feedstocks and that there is a potential for the installation of upwards of 100 units of 10-15,000 bbl/day capacity.

TABLE 1

OIL REFINING PROFILE (CONTINENTIAL USA)

	Hydroskimming	Low Conversion	High Conversion	Specialty Plants
Number of Refineries	24	59	61	41
Capacity, K BBL/day	560	4,685	9,215	475
% Capacity	4	31	62	3
Major's Operate, %	30	25	90	Low

Source - Oil and Gas Journal

TABLE 2

IMPACT OF CONVERSION OF EXISTING REFINERY CAPACITY TO ADVANCED COPROCESSING OF FUTURE HEAVY CRUDES

	Coal Consumption, MMTY	
	Feedstock	
Existing Refinery Type	Atmospheric Residuum	Residuum
Hydroskimming	9 - 11	3 - 6
Low Conversion	74 - 94*	30 - 50
High Conversion	146 - 185*	58 - 99*
	229 - 290	91 - 155

* Requires Shutdown of Existing Units
-- Prime Application for Coprocessing

FIGURE 1

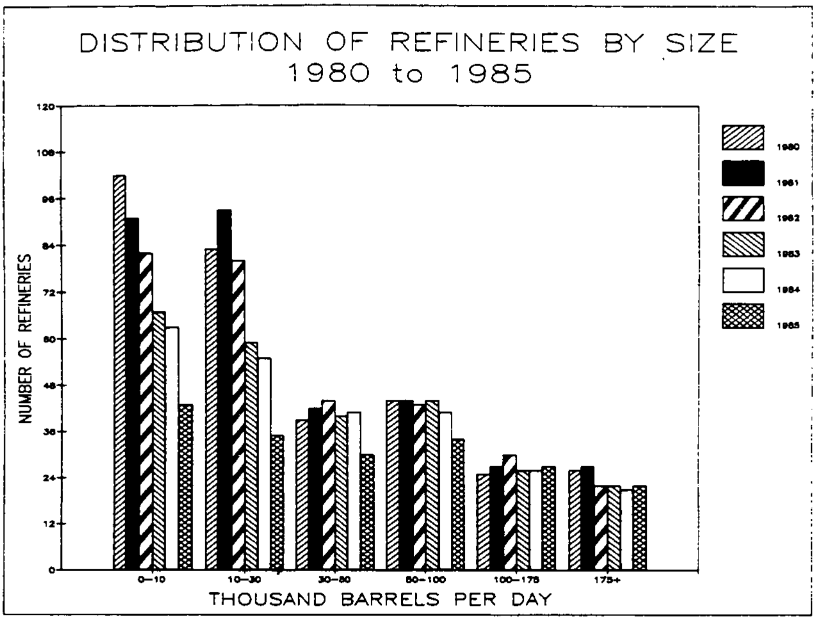

FIGURE 2
FLOW DIAGRAM
HIGH CONVERSION REFINERIES WITH COPROCESSING